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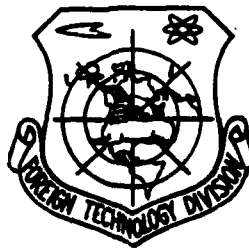
FOREIGN TECHNOLOGY DIVISION



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by

Liao Xianwang



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PARTICLE BEAM WEAPONS

Liao Xianwang

Particle beam weapons are actually miniaturized particle accelerators used for military purposes. They possess advantages over other antimissile devices even including laser weapons. To avert the danger of falling behind, both the Soviet Union and the United States have stepped up development in their efforts to turn particle beam weapons into both strategic defense weapons and in-space offensive weapons.

One day in November 1975 an American reconnaissance satellite carrying all kinds of reconnaissance equipment was quietly watching the world turn. Suddenly, overhead Semipalatinsk in the Central Asian part of the Soviet Union, it detected fission products of a suspected nuclear explosion. Actually, the Soviet Union had not carried out an underground nuclear test that day, and nor had they carried out a nuclear test in the atmosphere either. Continued reconnaissance detected more than seven or eight repetitions of this unusual phenomenon. It was not quite the coincidence it seemed. At that time US military intelligence experts were seriously concerned. Subsequently, after further intense and close reconnaissance, they came to the conclusion, after repeated deliberations, that this appearance of nuclear explosion protons could be evidence that the Soviet Union was carrying out research into the use of particle beam weapons. They also discovered that the Soviets were carrying out various experimental activities all associated with particle beam weapons.

In recent years, news reports in the Western press on the subject of this kind of particle beam weapon have been of two different opinions. One opinion considers them to be a type of mysterious weapon that destroys targets at the

speed of light, an unrivalled defensive weapon device with fast response time, great accuracy and a thousand times better precision than the present anti-missile systems. This opinion also considers that the Soviet Union has made breakthroughs in the field of particle beam technology which will allow them to be well ahead of the United States in deploying particle beam weapons in the early 1980s. This would therefore obsolete US strategic weapons. This is casting a cloud over the US development of strategic weapons and has spurred the US into stepping up the pace of developing particle beam weapons. An alternative view considers the technologies indispensable to particle beam weapons to be many. These technologies are complicated and for the time being are presenting a number of problems that are proving difficult to overcome. There is no chance of either the Soviet Union or the United States developing a viable weapon system from particle beam technology in the near future.

When all is said and done, what kind of a gadget is a particle beam weapon anyway?

The Mysterious Weapon Loses its Mystery

The Soviet Airforce and the Advanced Research Projects Agency of the US Department of Defense began to carry out research work on particle beam weapon devices and to conduct anti-particle beam weapon research and training exercises at least twenty years ago. Particle beam weapons are, in actual fact, particle accelerators used for the military purpose of destroying targets. They consist of :

1. Target detection, identification and tracking systems: to establish the initial flight parameters of the target, whether it be an attacking missile or satellite, and to compute its coordinates prior to firing the particle beam;
2. Particle accelerator system: to emit the particle beam;
3. Particle beam aiming and tracking system: to determine the effectiveness of target destruction or the missdistance measurement, to adjust the direction of fire and to open fire on the target again.

In order to destroy a target, a particle beam weapon must have high energy, strong current and very fast velocity. On the one hand, the Soviet Union and the United States are improving existing particle accelerators, while on the other hand they are researching and carrying out experiments with new types of particle accelerators: these are considered to be circular accelerators, resonance accelerators and linear induction accelerators. At present, the United States is carrying out the most important research and experimentation with resonance accelerators, the principles of which are illustrated in Figure 1 below. This type of accelerator has a special power source and the electrical energy supplied passes through a pulse forming

network which forms a pulse which then passes through an electron beam forming diode which forms the electron beam. It then passes into the accelerator section where the electron beam is concentrated into an electron wave. In the high frequency exciter section, the electrical power source at radio frequency is built into a travelling wave signal which absorbs the energy of the electron beam and becomes amplified. At the same time, the electron wave is accelerated by the field of the signal to a velocity approaching that of the speed of light.

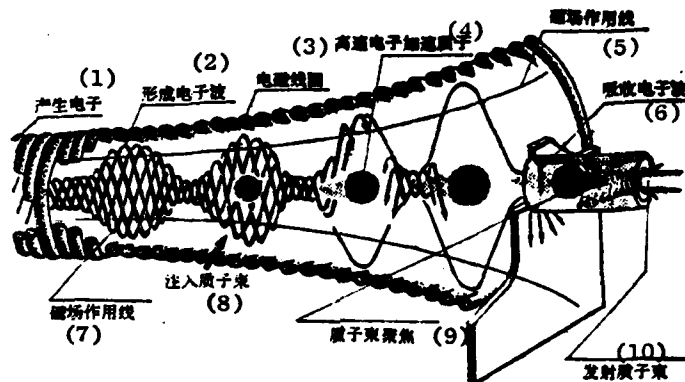


Fig. 1. The operating principles of a particle beam weapon device.

Key: (1) electron generation; (2) electron wave forming; (3) electromagnetic coil; (4) high velocity electron accelerated proton; (5) magnetic field effect line; (6) electron wave absorption; (7) magnetic field effect line; (8) proton beam injection; (9) proton beam focussing; (10) proton beam firing.

Hydrogen gas is injected into the gas injection valve and the ion injection section. Under the influence of the electron beam, the hydrogen atoms become ionized and lose their electrons to become protons. The ionization speed depends upon the hydrogen pressure, the volume, the energy and current of the electron beam, and the transverse section area of the accelerator cavity. The acceleration of the travelling wave field is transmitted to the protons captured by the field of the electron wave together with the electron wave. At the same time the electron wave expansion (increases from a radius of one centimeter to ten centimeters) also transmits axial acceleration to the protons. At the end of the accelerator, a scanning magnetic field separates the electrons from the protons which then become a high energy high current proton beam, which, after focussing, is fired.

The main parameters of the accelerator are:

The energy of each proton 3×10^6 electron volts

The electron beam current 3×10^4 amps

The electron beam power 10^{11} watts

The electrical power supply pulse voltage 3 megavolts

The pulse width 200 nanoseconds

Besides producing a high energy, high current particle beam, this type of resonance accelerator is small, light and low-cost. The United States began research on it in 1977 for deployment on satellites as part of the 'Marksman' program to use neutral particle beams against missiles and satellites.

Whether a particle beam can be effectively transmitted after firing is the most crucial aspect of a successful high energy, high current particle beam weapon. The main transmission problems are particle beam scattering, energy attenuation and channel instability. It is now generally recognised that charged particle beams are most suitable for transmission through the atmosphere and that neutral particle beams are most suitable for transmission in space.

If a particle beam is fired through the atmosphere, it initially collides with atmospheric molecules (Figure 2) and, as a result of heating, increasing the pressure of and ionizing atmospheric molecules, the energy of the particle beam is rapidly attenuated. If, for example, a proton beam of two centimeters diameter with an electron beam current of 5000 amperes, electron energy of one billion electron volts and a pulse width of 10^{-7} seconds, is fired, the pulse power loss in transmission is three megawatts per cm; the radiated power loss is thirty megawatts per cm. As a result of collisions with atmospheric molecules, the diameter of the particle beam is rapidly increased (for example, the diameter of an electron beam with electron energy of 500 million electron volts, after being transmitted one kilometer, increases from four centimeters to 132 meters). Consequently, the energy of the initial particle beam pulse must be sufficiently great that it can cut a tunnel through the atmosphere, causing ionization of the atmosphere resulting in the formation around the particle beam of a very thin, high temperature ionized tube. Collisions in the atmosphere between separated electrons, ions and a few atoms produces mesons (double electrons). If the first particle beam pulse can create a vacuum tunnel through the atmosphere, the particle beam pulses that follow can pass easily and the energy loss is reduced. However, in transmission the particle beam can exhibit twisting, coiling and contracting under the influence of hydrodynamic instability, the pulse electromagnetic wake effect, the non-linearity of the particle beam etc. Besides this, the charge created in the tube by the ionization and the particle beam polarity difference can weaken the electro-

static field of the particle beam, resulting in a reduction of the scattering caused by the repulsion of the particle beam's own charge. This is another reason why charged particle beams are appropriate for transmission through the atmosphere.

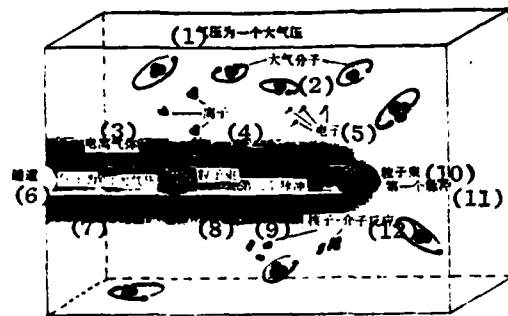


Fig. 2. Illustration of a particle beam fired through the atmosphere.

Key: (1) atmospheric pressure; (2) atmospheric molecules; (3) ionized gas; (4) ions; (5) electrons; (6) tunnel; (7) 0.1 atmospheres; (8) particle beam; (9) initial pulse; (10) particle beam; (11) initial pulse; (12) nucleon/meson reaction.

The ways in which a particle beam destroys a target after firing are very different depending upon the range and whether the beam hits or just touches the target (e.g. an attacking missile). (See Figure 3). Roughly speaking, it can burn a hole through or split the casing of the target, or ignite the warhead initiator; or destroy the electronic circuits of the guidance and control systems. The American physicist Chipps considers that to penetrate the casing of a missile requires energy of 2,000 joules per cm^3 to be concentrated upon the casing material. For a proton with energy of 200 million electron volts to penetrate one centimeter into light metal, requires energy of 10^{-12} joules to be applied and the firing energy of a proton beam that is to burn through a casing must be 64,000 joules/ cm^2 . Soviet experiments have shown that if 10^{23} electrons pass through one cm^2 every second and if the energy of 50% of the electrons is 1.65 million electron volts and if the electron beam pulse width is from 20 to 30 nanoseconds, it can burn a black spot 15 to 20 millimeters diameter on aluminum and the temperature of the aluminum will not exceed 200

degrees Celsius. From this it may be roughly estimated that: 1. When an attacking missile is within one kilometer and the energy of the particle beam fired is equal to or greater than one million joules, the target missile can be destroyed. Chipps also considers that in order to ignite the initiator of the warhead, the energy concentration that must be applied to the casing must be 200 joules/cm³. If the nuclear material is plutonium, destruction can be caused by particle beam radiation current of 100 to 125 joules/gram. Thus, under the above mentioned firing conditions, the nuclear material would be destroyed. 2. When the target is at a range of two kilometers and the particle beam energy is below 0.1 million joules, the particle beam may set up an electrostatic effect within the initiator of the nuclear warhead or prevent it from igniting or ignite the warhead. 3. If the target is at a range of three kilometers, and the particle beam energy is only 0.01 million joules, the particle beam may destroy the electronic circuits of the nuclear warhead initiator system or cause a failure of the guidance systems by creating electromagnetic radiation in the air. 4. If the target missile is at an even greater distance, and if the particle beam strikes the missile, part of the electronic instrumentation on board the missile may be seriously destroyed by the above mentioned radiation.

The above conditions are all deduced from theory, and although it seems a simple matter to theorize about such things, time must be spent on practical engineering before a whole series of crucial technological questions can be resolved. First, an extremely high efficiency light-weight generator must be constructed to provide the power source for the pulse to be used in a weapon system; to be used in space, it must be even lighter; second, a high energy compact accelerator is required; third, instantaneous detection, identification, tracking and aiming systems are required. Countering the above mentioned guided missiles with an accelerator of 30% efficiency, requires energy of 3×10^7 joules to be supplied in one hundredth of a second - this is equivalent to the total power output of 15,000 power plants of 2,000 megawatts. From this it can be seen that the requirements for realising a particle beam weapon are great

To satisfy such enormous energy requirements, tentative planning and experiment have been carried out with several different types of high efficiency short pulse discharge generator designs; compensating pulse alternating generators, single stage inertial storage generators and magnetic fluid generators. Of these, magnetic fluid generators have the best developmental future because they use high temperature high pressure gases to generate electricity and can directly use the exhaust gases from the jet nozzles of the carrier rocket engine, thus bringing about double utilization of the gases and increasing the effective utilization of the rocket fuel. Supplying the fuel

is also easier. The United States has designed a magnetic fluid generator which supplies 10 megawatts of power and weighs approximately 2000 kilos.

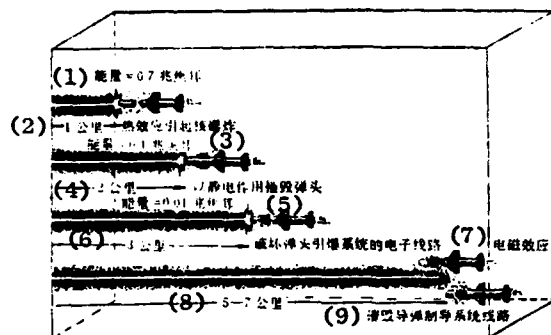


Fig. 3. A particle beam destroys targets at different ranges in different ways.
Key: (1) energy = 0.7 million joules; (2) at 1 kilometer - thermal effect causes nuclear explosion; (3) energy = 0.1 million joules; (4) at 2 kilometers - electrostatic effect destroys warhead; (5) energy = 0.01 million joules; (6) at 3 kilometers - destroys the electronic circuits of the warhead initiator system; (7) electromagnetic effect; (8) 5 to 7 kilometers; (9) destroys the circuits of the missile guidance system.

At the experimental facility at Semipalatinsk in Soviet Central Asia, electricity has been generated by a piston type magnetic fluid generator which may have derived its power from a nuclear explosion within two steel spheres fifteen meters in diameter and with walls one meter thick. The Soviet physicist Vylikov has stated in a paper that the Soviet Union expects some day to use a nuclear fusion magnetic fluid generator to produce several billion joules of energy. The single stage generator mentioned above was designed by the University of Texas in the United States. It has a pulse output power of 10×10^6 watts and can deliver 56×10^4 amps of current in 0.7 seconds. It is said that this generator uses special brush devices to convert the kinetic energy of a rotor (5,200 rpm) to electrical energy. Although this generator supplies a uni-directional pulse, is small and low-cost, it has the disadvantages that the

discharge voltage is low and the discharge speed is low. They are now planning to build an even larger generator which will deliver 9.4×10^7 watts of power in one millisecond, yet still small with a diameter of only forty centimeters and a length of 1.2 meters.

The problems of ensuring that the particle beam hits the target concern detection and tracking as well as aiming the particle beam. As the particle beam weapon must fire the particle beam directly at the target, aiming precision is of paramount importance. The greater the range, the greater the precision. In this case of satellite borne particle beam weapons, if the angle of the target is from 20 to 0.1 elements of an arc, the aiming precision of the particle beam must be from 1 to 0.03 elements of an arc. One type of so-called laser radar / inertial platform combination system has the following operating principles: 1. The target data receiver receives the target flight parameters, and the computer converts this in real-time into inertial reference data; 2. commands are determined, and the firing platform turns towards the bearing of the target; 3. the target is tracked by the target detection and tracking laser radar, and the precise parameters of the target are established; 4. the particle beam firing angle is set up; 5. the particle beam is fired; 6. the effectiveness of the attack is determined and the missdistance is computed; 7. the feedback path is entered to correct the aiming error. At present, on the one hand research is being carried out to enhance the accuracy of detection devices while on the other hand the problem of tracking neutral particle beams is being explored. Experiments have shown that electron beams can reflect radar waves; in the case of neutral particle beams, if a fixed wave-length laser illumination is used to excite a neutral particle beam, it will produce a resonating scatter signal and then an infrared detector can be used for detection. The missdistance measurement can thus be found.

Gold is not Pure Enough. The Future is Difficult to Predict.

To sum up, so-called particle beam weapons are actually miniaturized particle accelerators used for military purposes. Compared with other anti-missile devices, including laser weapons, they possess the following advantages: 1. The energy of a particle weapon is concentrated and can destroy a target efficiently; 2. they can be used under any weather conditions, whereas lasers are ineffective in cloud; 3. particle beam weapons have fast response time, carrying out an attack at the speed of light; 4. they are unaffected by thermal effects and nuclear radiation in space; 5. as far as the American / Soviet arms race is concerned, particle beam weapons are not limited by the 'Nuclear Test Ban Treaty' or 'S.A.L.T.'. Consequently, to avert the danger of falling behind, both sides have stepped up development in their efforts to turn particle beam weapons into both strategic defensive weapons and in-space offensive weapons.

However, other experts consider that particle beam weapons have many weaknesses. 1. The key technological problems of the weapon system are not easy to overcome. 2. The cost is too high, making them uneconomic and unrealistic. Once the technological problems have been solved, to deploy the system in space will require the expenditure of US\$ 1.5 million before a single satellite or missile can be destroyed. To protect American military installations around the world will require global coverage by orbiting military space stations, and, if they are to be 1000 kilometers apart, there will need to be 406 such space stations. The expense entailed is really difficult to estimate. 3. If they use a nuclear power source, and if contamination should occur, the consequences would be unimaginable. 4. In theory, if they are to avoid being destroyed, in the five seconds after enemy missiles have been detected, they must destroy one after another one thousand targets at a range of one thousand kilometers. In terms of today's science and technology, it is difficult to construct such search, aim and fire command systems. 5. Some people consider that all that need be done is to explode a nuclear device in space or in the stratosphere, and normal firing of particle beams will be prevented or disrupted within a certain area; or broadcast chaff to interfere with target identification. 6. At present, no detailed consideration has been given to the effect of the bending of the track of particle beams by the Earth's magnetic field, the effect of lightning strikes on particle beams passing through the atmosphere, and other distortions which may throw off the aim of particle beams.

Experts forecast that new types of particle accelerators will be in military use within the next twelve years, but it is difficult to state with any certainty when a particle beam weapon will be constructed that matches the demand of actual combat. Whatever the future of particle beam weapons, we can only wait and see.

National Defense illustrations

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